FISHERY DATA SERIES NO. 74

STOCK ASSESSMENT OF ARCTIC GRAYLING IN THE SALCHA AND CHATANIKA RIVERS[1]

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December 1988

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-4, Job No. G-8-1.

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ABSTRACT

Arctic grayling *Thymallus arcticus* were captured by electrofishing in the Salcha River and by electrofishing, hook-and-line, and seining in the Chatanika River in 1988. Stock assessment was accomplished through estimation of population abundance, age composition, and size composition. Population abundance in a 16 kilometer section of the Salcha River was 2,181 Arctic grayling greater than 149 millimeter fork length. Age composition in both rivers was similar, with age 5 Arctic grayling strongly represented. Salcha River Arctic grayling tended to be larger than Chatanika River Arctic grayling. Growth characteristics of these two stocks indicate that Salcha River fish grow faster, on average, than Chatanika River fish after age 3. Sustained yield of Arctic grayling in these two stocks could not be calculated from the available population and fishery data. Assessment of the Salcha and Chatanika Arctic grayling stocks should continue. Future assessment should emphasize additional tagging to estimate population survival rates.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, population size, harvest, fishing effort, age composition, size composition, relative stock density, electrofishing, Salcha River, Chatanika River, Tanana River Drainage.

INTRODUCTION

The Salcha and Chatanika Rivers presently support two of the largest Arctic grayling *Thymallus arcticus* fisheries in the Tanana River drainage of interior Alaska. Although these fisheries are large, very little is known about the stocks of Arctic grayling in these streams. As recreational fishing pressure increases in the Tanana drainage, these two fisheries will grow. Knowledge of fishery characteristics and the dynamics of Arctic grayling in these streams is important to fishery managers. Stock assessment in these two streams must be implemented before sound management practices can be employed. Lessons learned from the Chena River fishery reinforce the need to link stock assessment with ultimate management decisions (Holmes et al. 1986; Clark in prep.).

This report summarizes stock assessment work performed on the Salcha and Chatanika Arctic grayling fisheries from 1952 to 1988. By presenting all data pertinent to these two fisheries, decisions regarding future stock assessment work can be made. Summarized data will allow managers to assess the status of these two fisheries in light of available data.

The research objectives for 1988 were:

1) to estimate the absolute abundance of Arctic grayling in a 16 km long stretch of the Salcha River;

2) to estimate the age composition of Arctic grayling in the Salcha and Chatanika Rivers; and,

3) to estimate the mean fork length at age of Arctic grayling in the Salcha and Chatanika Rivers.

Fishery Descriptions

The Salcha and Chatanika Arctic grayling fisheries are much alike, but each fishery has distinct differences that affect the progress of stock assessment work. Each fishery is described by hydrologic characteristics, methods of access, and past performance of the recreational fishery. Historic population data are presented as a series of tables in the Appendix.

Salcha River:

As with other runoff streams of the Tanana drainage, the Salcha River flows south out of the Tanana Hills into the Tanana River (Figure 1). The river is characterized by high gradient, with long shallow runs and exposed gravel bars. Holmes (1984) described four separate areas encompassing the lower 192 km of the Salcha River. The upstream section is characterized by a narrow (≈18 m wide), shallow (≈0.5 m deep) channel with numerous protruding boulders. Average water velocity in late June was 1 m/sec, with a gradient of 4.2 m/km. The upper midstream section is characterized by a wider (≈33 m), deeper (≈1.2 m) channel with no protruding boulders. Water velocity and gradient are similar to the upstream section. The lower midstream section is characterized by a 68 m wide and 2.1 m deep channel. Average velocity in this section was 0.8 m/sec, while average gradient was 1.8 m/km. The downstream section is

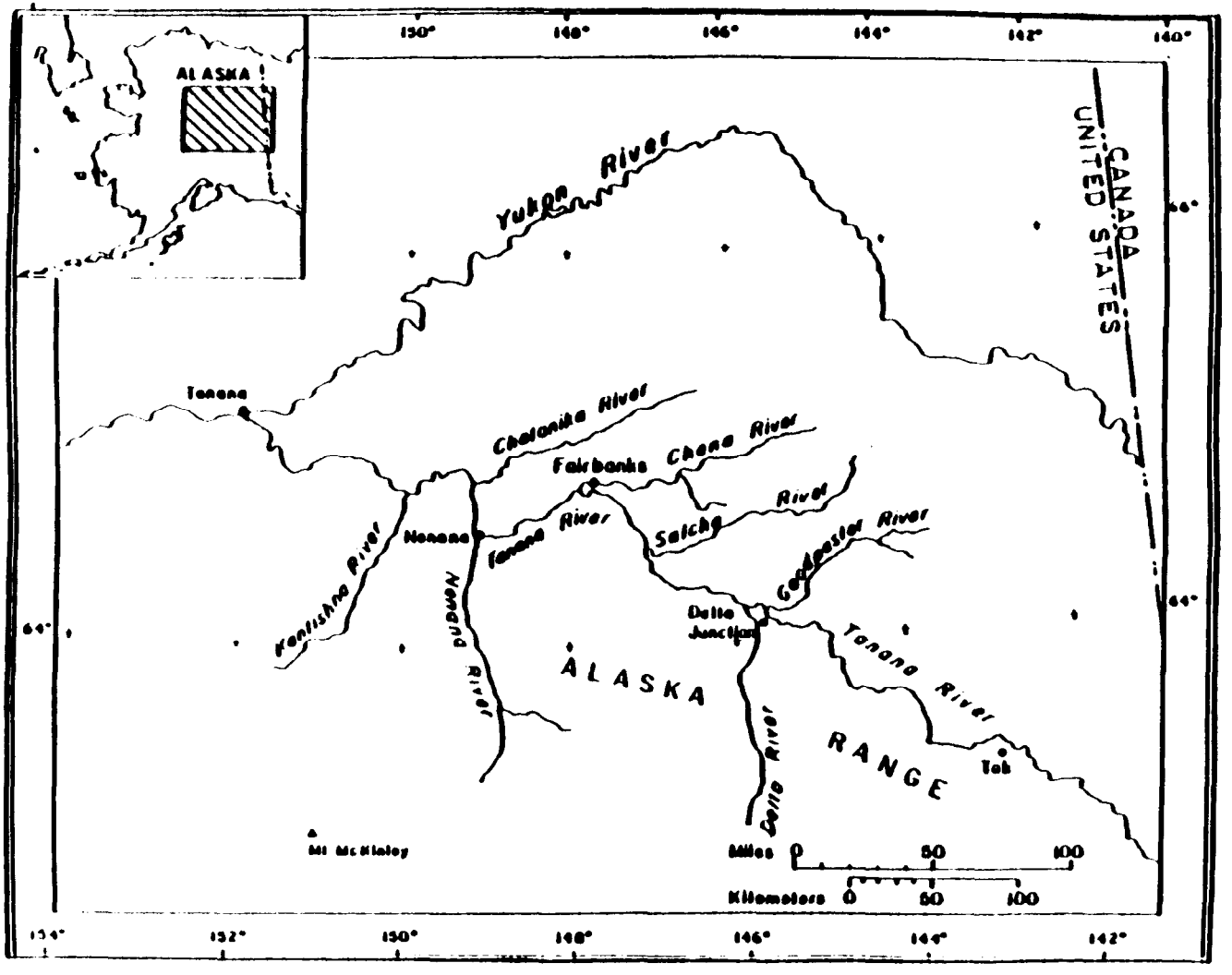

Figure 1. The Tanana drainage.

characterized by a single, wide channel with a water velocity of 0.8 m/sec and a gradient of 1.1 m/km. Average stream flow in the downstream section during summer (May-July) has ranged from a low of 50.95 m^3/sec in 1980 to a high of 123.86 m^3/sec in 1984 (USGS 1976-1986). The majority of recreational fishing occurs in the downstream section (river km 0 to river km 80).

Recreational fishing targets Arctic grayling, chinook salmon *Oncorhynchus tshawytscha*, summer chum salmon *Oncorhynchus keta*, northern pike *Esox lucius*, burbot *Lota lota*, and whitefish species *Coregonus* spp. The Salcha River is accessed by car from the Richardson Highway at Milepost 348. Access by car is limited to a 1.6 km area adjacent to the Salcha River State Recreation Area. Riverboat and floatplane provide much of the access to upstream areas of the Salcha River. In 1987, regulations were promulgated to protect the Arctic grayling fishery from decline. These regulations are:

1) restrict the harvest of Arctic grayling to fish 305 mm (12 in) or greater in total length;

2) restrict methods of harvest to unbaited artificial lures only; and,

3) eliminate the harvest of Arctic grayling during the spawning period (1 April to the first Saturday in June).

Prior to 1977, very little recreational fishery data were collected. Creel census was conducted during the summers of 1953 through 1958. Harvest was not estimated, but angler harvest rates ranged from 0.48 Arctic grayling per hour to 1.09 Arctic grayling per hour (Warner 1959; Table 1). Incomplete creel censuses were also conducted in 1963 and 1964; harvest rates were 0.67 and 0.64 fish per hour, respectively (Roguski and Winslow 1969). The first complete harvest survey was conducted in 1968. A total of 7,048 Arctic grayling were harvested in 7,035 angler-hours for a harvest rate of 1.00 fish per hour (Roguski and Winslow 1969). A harvest survey was also conducted in 1974, with an estimated 4,728 Arctic grayling harvested in 11,284 angler-hours (Kramer 1975).

Since 1977, Mills (1979-1988) has estimated harvest and angling effort on the Salcha River. Annual harvest of Arctic grayling has averaged 7,153 fish, ranging from 3,983 in 1981 to 13,305 in 1984 (Table 2). Angling effort for all species of sport fish has averaged 11,043 angler-days, ranging from 8,090 angler-days in 1981 to 14,126 angler-days in 1982.

In addition to harvest data provided by Mills (1988), Baker (1988) conducted a creel survey of Salcha River anglers in 1987 (May through August). Catch rate was estimated at 0.66 (SE = 0.40) Arctic grayling harvested per angler-hour.

Chatanika River:

The Chatanika River is a runoff stream that flows southwest out of the White Mountains, draining through Minto Flats into the Tolovana River (Figure 1). Formed by the confluence of Faith and McManus Creeks, the Chatanika River parallels the Steese Highway for approximately 70 km. The Chatanika River is also crossed at Mile 11 of the Elliot Highway. Townsend (1987) described

Table 1. Summary of recreational effort and catch rate estimates for Arctic grayling harvested from the Salcha and Chatanika Rivers, 1953-1958, 1960, 1963-1964, 1968, 1974, 1987.[1]

	Salcha River			Chatanika River		
Year	Interviews	Man-hours	GR/hr[2]	Interviews	Man-hours	GR/hr
1953	102	344	0.48	460	955	0.49
1954	132	646	0.84	243	529	0.78
1955[3]	174	728	1.09	69	294	0.13
1956[3]	391	1,659	0.83	66	223	0.27
1957[3]	86	321	0.78	62	177	0.18
1958[3]	108	423	1.01	68	151	0.76
1960	ND	2,600	1.22	---	---	---
1963	275	---	0.67[4]	---	---	---
1964	409	1,816	0.64	---	---	---
1968	2,013[5]	7,035[5]	1.00	---	---	---
1974	827	11,284[5]	0.42	408	27,250[5]	1.02
1987	152	---	0.66	30	---	0.02

[1] Statistics taken from Warner (1959) for 1953-1958, Reed (1961) for 1960, Roguski and Winslow (1969) for 1963-1968, Kramer (1975) for 1974, and Baker (1988) for 1987.

[2] GR/hr is the number of Arctic grayling harvested per man-hour.

[3] From 1955 through 1958 there was a 12 inch minimum length limit for Arctic grayling on the Chatanika River (Warner 1959).

[4] This catch rate includes salmon (Roguski and Winslow 1969).

[5] Data expanded from sample time/area to the entire fishery.

Table 2. Recreational Arctic grayling harvest and angling effort on the Salcha and Chatanika Rivers, 1977-1987 (taken from Mills 1979-1988).

Year	Salcha River		Chatanika River	
	Harvest[1]	Effort[2] (man-days)	Harvest	Effort (man-days)
1977	6,387	8,167	6,737	9,925
1978	9,067	9,715	9,284	10,835
1979	5,980	14,788	6,121	4,853
1980	5,351	8,858	5,143	5,576
1981	3,983	8,090	3,808	4,691
1982	6,843	14,126	6,445	9,417
1983	9,640	11,802	9,766	10,757
1984	13,305	8,449	4,180	8,605
1985	5,826	13,109	7,404	10,231
1986	7,540	13,792	2,692	7,783
1987	4,762	10,576	5,619	11,065
Averages	7,153	11,043	6,109	8,522

[1] Harvest is the estimated number of Arctic grayling taken.

[2] Effort is the number of man days expended for all fish species.

three reaches of the Chatanika River. Much of the upper reach (Long Creek to the headwaters) is accessible from the Steese Highway and supports recreational fishing for Arctic grayling, three species of whitefish, and two species of Pacific salmon. The middle reach is also accessible from the Steese and Elliot highways and supports fishing for these species as well. The lower reach is accessible by riverboat from the Elliot Highway and the Murphy Dome Road Extension. This reach of the Chatanika River supports northern pike, sheefish *Stenodus leucichthys*, and burbot fishing.

The Chatanika River is much more accessible than the Salcha River, mainly due to a long history of placer mining in the area. As of 1986, there were placer mining operations on portions of Faith, Sourdough, No Name, and Flat Creeks of the upper Chatanika River (Townsend 1987). Townsend (1987) also reported mining activity on Goldstream Creek in the lower Chatanika. There are four recreation sites on the Chatanika River; 39-Mile Steese Highway campground, 11-Mile Elliot Highway (one campground and one picnic area), and 61-Mile Steese Highway campground.

Although extensive studies of the Chatanika River Arctic grayling fishery were performed before statehood (Warner 1959), very little creel census data were obtained prior to 1977. Angler catch rates were estimated during summer 1953-1958, ranging from 0.13 Arctic grayling per hour in 1955 to 0.78 Arctic grayling per hour in 1954 (Warner 1959; Table 1). Fishery managers during this period thought that excessive harvest of sub-adult grayling was causing declines in fish abundance and angler catch rates (Wojcik 1954, 1955). A 305 mm (12 inch) minimum length limit for Arctic grayling was enforced between 1955 and 1958, but was subsequently removed in 1959 (Warner 1959).

A creel census of the Chatanika River Arctic grayling fishery was conducted by Kramer (1975) in 1974. An estimated 27,250 man-hours were expended with a catch rate of 1.02 Arctic grayling per hour. From 1977 through 1987, harvest of Arctic grayling was monitored by Mills (1979-1988). Annual harvest averaged 6,109 fish during this period, with 8,522 man-days of effort (Table 2). Annual harvests during this period ranged from 2,692 fish in 1986 to 9,766 fish in 1983.

In addition to harvest data provided by Mills (1988), Baker (1988) conducted a creel survey of Chatanika River (Elliot Highway area) anglers in 1987 (May through June). Catch rate was estimated at 0.02 Arctic grayling harvested per angler-hour.

METHODS

Estimation of Abundance - Salcha River

Population abundance was estimated in a 16 km long study section of the Salcha River. This study section was bounded upstream at river km 36.8 and bounded downstream at river km 20.8 (Trans-Alaska Pipeline crossing; Figure 2). Use of a 16 km long section minimized emigration of fish from the study section during the estimation experiment. The study section was further subdivided into three study areas. The downstream, midstream, and upstream areas were

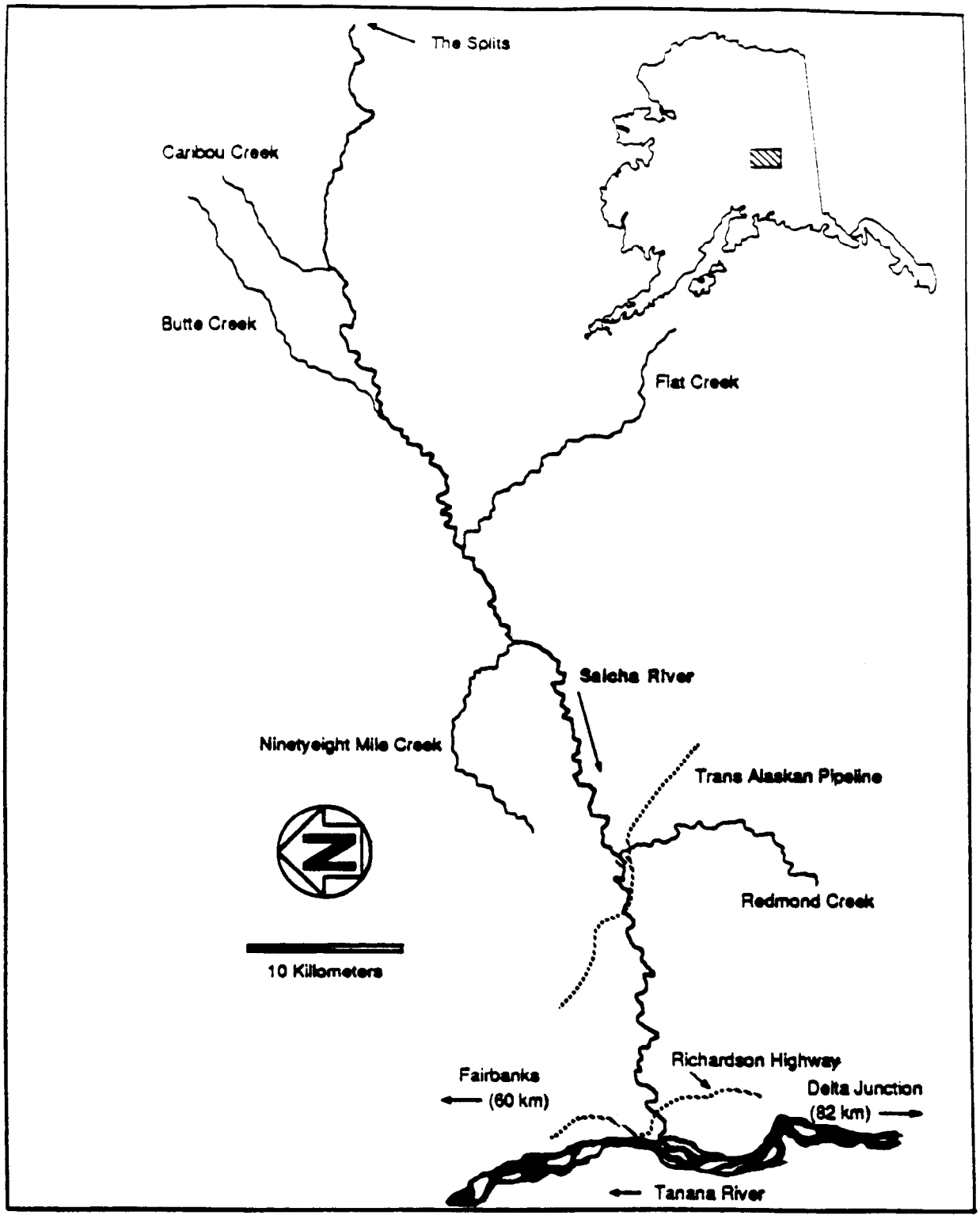

Figure 2. Salcha River below the Splits (study area is from Trans Alaskan Pipeline crossing upstream to solid bar).

4.8, 6.4, and 4.8 km long, respectively. Collection of mark and recapture data was segregated by area to facilitate the estimation of fish movement within the study section. Data were collected with a pulsed-DC electrofishing boat using a variable voltage pulsator and 10 mm diameter steel cable anodes. The unpainted bottom of the boat served as the cathode.

Mark and recapture samples were taken during three events, each 3 days long. Events started at the upstream end of the study section. One event consisted of electrofishing along each bank, collecting as many fish as possible. The events were further divided into 20 minute long runs. Sampling both banks along approximately 2 km of river required two runs. After two runs were completed, the fish were measured to the nearest 1 millimeter of fork length (FL), tagged with Floy FD-67 internal anchor tags, finclipped (adipose fin), and released. The adipose fin was removed to allow determination of mark status if tags were lost. The use of runs allowed for even distribution of marked fish in the study section. The first event occurred on 24 through 26 May; the second event on 31 May through 2 June; and the last event on 6 through 8 June. Additional sampling was performed below the study section on 9 June. For purposes of this experiment, event one was designated the marking sample and events two and three were designated the recapture sample (with replacement).

Population abundance of Arctic grayling greater than 149 mm FL was estimated with the modified Petersen formula of Bailey (1951, 1952) and the modified Petersen formula of Bernard (Bernard, pers. comm.; Evenson 1988). The assumptions necessary for accurate estimation of abundance are (adapted from Seber 1982):

1) the Arctic grayling population in the study section must be closed to growth, recruitment, immigration, and emigration between sampling events;

2) all Arctic grayling have the same probability of capture during the first sampling event or during the last sampling event or tagged Arctic grayling must completely mix with untagged Arctic grayling between sampling events;

3) no tags can be lost between sampling events;

4) tagged Arctic grayling must behave as do untagged Arctic grayling between sampling events; and,

5) tagged Arctic grayling must have the same mortality rate as untagged Arctic grayling between sampling events.

A Kolmogorov-Smirnov test was unable to detect significant changes in capture probabilities of marked fish by length at first capture ($DN = 0.246$; $P > 0.10$). Therefore, the mark-recapture data were not biased with respect to differing capture probability in the population and assumption 2 was met. Removal of the adipose fin assured accurate recording of marked fish upon recapture, so assumption 3 was also met. Each of the three events were set 1 week apart from one another to maximize mixing of tagged and untagged Arctic

grayling, and minimize recruitment by growth or migration. A chi-squared test was performed to determine the extent of movement in the study section between areas. Significant interarea movement of Arctic grayling in the study section was observed between the marking (first event) and recapture (second and third events) samples of the experiment ($\chi^2 = 7.20$, $df = 2$, $P < 0.05$). Since interarea movement was observed between sampling events, it was inferred that Arctic grayling must have been migrating in and out of the study section between sampling events. The modified Petersen estimator of Bernard was used to compensate for this recruitment. The additional assumptions necessary for accurate use of this estimator are (taken from Evenson 1988):

6) no Arctic grayling tagged in the midstream area migrate out of the study section; and,

7) a single process causes upstream movement, and a single process causes downstream movement.

The modified Petersen estimator that accounts for movements of tagged fish is:

$$(1) \qquad \hat{N} = \frac{\{ M_1(1-\hat{\theta}_d) + M_2 + M_3(1-\hat{\theta}_u) \} \{C + 1\}}{R_{..} + 1}$$

where:

M_x = the number of Arctic grayling marked in the first event in section x (x = 1, 2, and 3 for the downstream, midstream, and upstream areas, respectively);

$R_{..}$ = the number of Arctic grayling recaptured during events two and three;

θ_z = the probability that an Arctic grayling will move out of an area in the z direction (upstream or downstream);

C = the catch made during events two and three; and,

N = the abundance of Arctic grayling in all areas at the start of the second event.

The probabilities of movements were estimated by:

$$(2) \qquad \hat{\theta}_d = \frac{M_2(R_{32} + R_{21})}{R_{2.}(M_3 + M_2)} \qquad (3) \qquad \hat{\theta}_u = \frac{M_2(R_{12} + R_{23})}{R_{2.}(M_1 + M_2)}$$

where:

R_{xy} = the number of Arctic grayling that were marked in area x during the first event and were recaptured in area y during the second and third events; and,

$R_{2.}$ = the number of Arctic grayling that were marked in the midstream area during the first event and were recaptured during the second and third events.

Variance of the abundance estimate was calculated by bootstrap analysis as described in Efron (1982) and performed in Clark and Ridder (1988). Variances of the probabilities of movements were also calculated using this procedure.

Estimation of Age and Size Composition

Estimates of age and size composition are used to characterize the structure of Arctic grayling stocks in the Tanana drainage. Changes in age and size composition often indicate serious fishery or environmental effects on recruitment and survival. When population abundance estimates are not possible or not cost effective, these indices of stock structure can help managers to compare the health of fishery stocks.

Salcha River:

Age and size data were collected in conjunction with population abundance sampling between 24 May and 8 June. Additional age and size data were collected downstream of the study section on 9 June. A sample of scales was taken from the preferred zone[1] of each newly captured fish. Fork length was measured to the nearest 1 millimeter. Scales were processed by cleaning in a solution of hydrolytic enzyme and then mounting two scales from each fish on gum cards. These gum cards were used to make impressions of the scales on triacetate film (30 seconds at 7,000 kg/cm^2, at a temperature of 97°C). Ages were determined by counting annuli on these impressions with the aid of a microfiche reader.

The accuracy of age and size composition estimates are dependent on the selectivity of the sampling gear. A pulsed-DC electrofishing boat was used to collect these data and has been shown to exhibit bias in capturing all sizes of Arctic grayling greater than 149 mm FL (Clark and Ridder 1988). However, no significant change in capture probability of marked Arctic grayling was detected during mark-recapture sampling on the Salcha River. Therefore, it can be assumed that age and size samples taken with the electrofishing boat were not significantly different than the true age and size composition of the Salcha River stock at the time these samples were taken.

An unbiased estimate of the proportion of Arctic grayling in each age class is:

$$(4) \qquad \hat{p}_i = \frac{y_i}{n}$$

[1] The preferred zone for Arctic grayling is an area approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin.

where:

y_i = the number of Arctic grayling of age i in the sample; and,
n = the number of Arctic grayling in the sample.

The unbiased variance of this proportion is:

$$(5) \qquad V[\hat{p}_i] = \frac{\hat{p}_i (1 - \hat{p}_i)}{n - 1}$$

Size composition of the Salcha River stock was described with the incremental Relative Stock Density (RSD) indices of Gablehouse (1984). The RSD categories for Arctic grayling are: Stock (150 to 269 mm FL); Quality (270 to 339 mm FL); Preferred (340 to 449 mm FL); Memorable (450 to 559 mm FL); and Trophy (greater than 559 mm FL). RSD indices were estimated with equations 4 and 5, substituting the RSD categories for age classes.

Chatanika River:

Age and size composition data were collected during 15 through 26 August and 7 through 20 September. Samples were collected with a pulsed-DC electrofishing boat, seines, and hook-and-line gear. Data collection procedures were identical to the Salcha River study. Sampling was restricted to an area 16 km upstream and 16 km downstream of the Elliot Highway bridge (Figure 3).

Hook-and-line and electrofishing gear are known to be selective for larger Arctic grayling, causing bias in age and size estimates. No mark-recapture experiment was performed to detect gear selectivity, although the absence of significant gear selectivity on the Salcha River was assumed for samples taken on the Chatanika River. No significant gear selectivity was found in electrofishing samples taken on the Chena River in 1988 (Clark, in prep.). Assuming gear selectivity was not significantly biasing age and size samples on the Chatanika River, age and size compositions were estimated with equations 4 and 5.

Estimation of Length at Age

Length at age information was used to characterize growth of Arctic grayling in the Salcha and Chatanika Rivers. Data collected during 1986 (Clark and Ridder 1987), 1987 (Clark and Ridder 1988), and 1988 were used to construct a growth model for each of these stocks. Mean lengths were calculated as the arithmetic mean fork length at each age. The von Bertalanffy growth model (Ricker 1975) was chosen to equate age with average length of fish in the stock. The parameters of the model were fitted by nonlinear regression using Marquardt's compromise (Marquardt 1963). The three parameters (L_∞, K, and t_0) were fitted 270 times with differing initial values. The range of initial values for the model were L_∞: 350 to 600 by 50; K: 0.0 to 0.4 by 0.1; and t_0: -2.0 to 2.0 by 0.5. The set of estimates with the lowest sums squared deviations was selected as the best fit to the data.

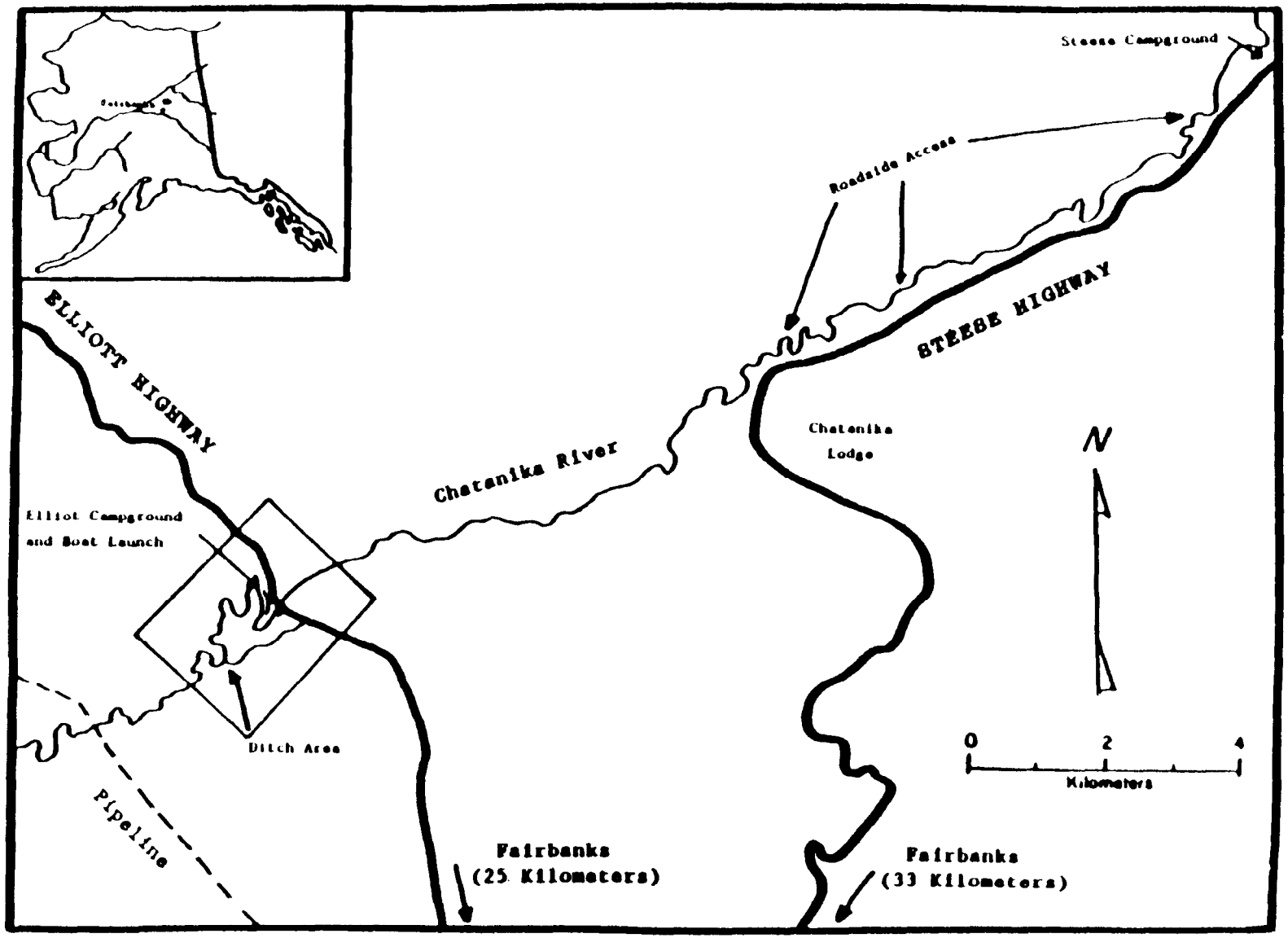

Figure 3. Study section on the Chatanika River (section enclosed in box).

RESULTS

Salcha River

Population abundance of Arctic grayling in the 16 km study section was estimated for the period 31 May through 2 June. The bootstrap modified Petersen estimate (accounting for fish movement) was 2,181 fish (SE = 542 fish; Table 3). This bootstrap estimate of abundance was slightly lower than the calculated estimate of 2,215 fish. Bootstrap probabilities of movement were lower than their respective calculated estimates (Table 3). For comparison, the modified Petersen estimate of Bailey (1951, 1952) was calculated. This estimate was 2,731 fish (SE = 437 fish) present during the first sampling event (24 through 26 May).

Age 3 and age 5 Arctic grayling dominated the Salcha River stock in 1988. Twenty percent of the stock were age 3, while 30% of the stock were age 5 (Table 4). Age 4, and age 6 through 8 Arctic grayling tended to be equally represented in the stock.

Forty-six percent of the Salcha River stock were sub-adult (<270 mm FL; Table 5). The average age at which Salcha River Arctic grayling reach the fork length of 270 mm is 4.6 years (Clark unpublished). Therefore, most of the age 5 fish would be quality size or larger. Quality size fish were next most abundant in the study section, with 36% of the stock greater than 269 mm FL and less than 340 mm FL. Eighteen percent of the stock was preferred size and less than 1% was memorable size (Table 5).

Average fork length at age of Salcha River Arctic grayling was successfully modelled (Table 6; Figure 4). With the exception of age 11 samples, standard deviation of length at age was fairly uniform among ages (Table 7). Additional samples are probably needed to accurately measure the variation in length of 11 year old fish. Inaccuracy in aging Arctic grayling this old probably accounts for some of the variation. No samples of age 12 or older Arctic grayling were taken from the Salcha River.

Chatanika River

Age class composition was estimated from samples taken during 15 through 26 August and 7 through 20 September. Of the 626 Arctic grayling captured from the Chatanika River, 77% were captured with electrofishing, 19% with hook-and-line, and 4% with beach seine. Age 5 fish were most abundant in the Chatanika River, accounting for 42% of the stock (Table 4). Less than 10% of the stock was composed of newly recruited age 3 fish, suggesting poor recruitment of the 1985 year class.

Although there were few young fish in the Chatanika River this year, 61% of the stock were sub-adult (<270 mm FL; Table 5). The average age at which Chatanika River Arctic grayling reach a fork length of 270 mm is 5.4 years (Clark unpublished). Therefore, most of the age 5 fish may not have reached 270 mm FL at the time of sampling. Of the remaining 39% of the stock, 37% were quality size and 2% were preferred size (Table 5). No memorable size fish were captured on the Chatanika River in 1988.

Table 3. Population abundance estimate of Arctic grayling (≥ 150 mm FL) in a 16 km section of the Salcha River, 24 May through 8 June, 1988.

Parameter	Calculated or Known Quantity	Bootstrap Estimate
M_1	51	51
M_2	90	90
M_3	67	67
C	378	378
$R_{..}$	28	28
R_{11}	5	5
R_{12}	1	1
R_{13}	0	0
R_{21}	3	3
R_{22}	4	4
R_{23}	0	0
R_{31}	2	2
R_{32}	5	5
R_{33}	8	8
Θ_d	0.655	0.589
Θ_u	0.091	0.045
$\hat{N}$ (Evenson 1988)	2,215	2,181
SE	Unknown	542
$\hat{N}$ (Bailey 1951, 1952)	2,731	Bootstrap not performed
SE	437	Bootstrap not performed

Table 4. Estimates of proportional contributions of each age class and standard error for Arctic grayling (≥ 150 mm FL) captured from the Salcha and Chatanika River stocks, 1988[1].

	Salcha River				Chatanika River			
Age Class	n[2]	p[3]	SE[4]	CV[5]	n	p	SE	CV
2	17	0.029	0.007	24.1	22	0.043	0.009	20.9
3	116	0.200	0.017	8.5	44	0.085	0.012	14.1
4	83	0.143	0.014	9.8	63	0.122	0.014	11.5
5	175	0.301	0.019	6.3	216	0.419	0.022	5.2
6	58	0.100	0.012	12.0	48	0.093	0.013	14.0
7	54	0.093	0.012	12.9	55	0.107	0.014	13.1
8	51	0.088	0.012	13.6	61	0.118	0.014	11.9
9	22	0.038	0.008	21.0	5	0.010	0.004	40.0
10	4	0.007	0.003	42.8	1	0.002	0.002	100.0
11	1	0.002	0.002	100.0	0	0.000	---	---
Totals	581	1.000	---	---	515	1.000	---	---

[1] Arctic grayling were sampled from the Salcha River between 24 May and 9 June, 1988. Arctic grayling were sampled from the Chatanika River between 15 and 26 August and 7 and 20 September, 1988.
[2] n = sample size.
[3] p = proportion of Arctic grayling in the population.
[4] SE = population standard error of the proportion.
[5] CV = coefficient of variation of the proportion expressed as a percentage.

Table 5. Summary of Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) in the Salcha and Chatanika Rivers, 1988[1].

	RSD Category[2]				
	Stock	Quality	Preferred	Memorable	Trophy
Salcha River					
Number sampled	280	217	110	1	0
RSD	0.461	0.357	0.181	0.002	---
Standard Error	0.020	0.019	0.016	0.002	---
CV (%)	4.3	5.3	8.8	100.0	---
Chatanika River					
Number sampled	361	221	13	0	0
RSD	0.607	0.371	0.022	---	---
Standard Error	0.020	0.020	0.006	---	---
CV (%)	3.3	5.4	27.3	---	---

[1] Arctic grayling were sampled from the Salcha River between 24 May and 9 June, 1988. Arctic grayling were sampled from the Chatanika River between 15 and 26 August and 7 and 20 September, 1988.

[2] Minimum lengths for RSD categories are (Gablehouse 1984):
Stock - 150 mm FL;
Quality - 270 mm FL;
Preferred - 340 mm FL;
Memorable - 450 mm FL; and,
Trophy - 560 mm FL.

Table 6. Parameter estimates and standard errors of the von Bertalanffy growth model[1] for Arctic grayling from the Salcha and Chatanika Rivers, 1986-1988.

	Salcha River		Chatanika River	
Parameter	Estimate	Standard Error	Estimate	Standard Error
L_∞	489	19	375	11
K	0.156	0.015	0.189	0.017
t_o	-0.419	0.164	-1.014	0.198
$Corr(L_\infty, K)$	-0.985	---	-0.983	---
$Corr(L_\infty, t_o)$	-0.876	---	-0.894	---
$Corr(K, t_o)$	0.942	---	0.959	---
Sample size	1,198		1,469	

[1] The form of the von Bertalanffy growth model (Ricker 1975) is as follows: $l_t = L_\infty (1 - exp(-K (t - t_o)))$. The parameters of this model were estimated with data collected during 1986 through 1988. Estimation was accomplished through nonlinear regression using the Marquardt compromise (Marquardt 1963).

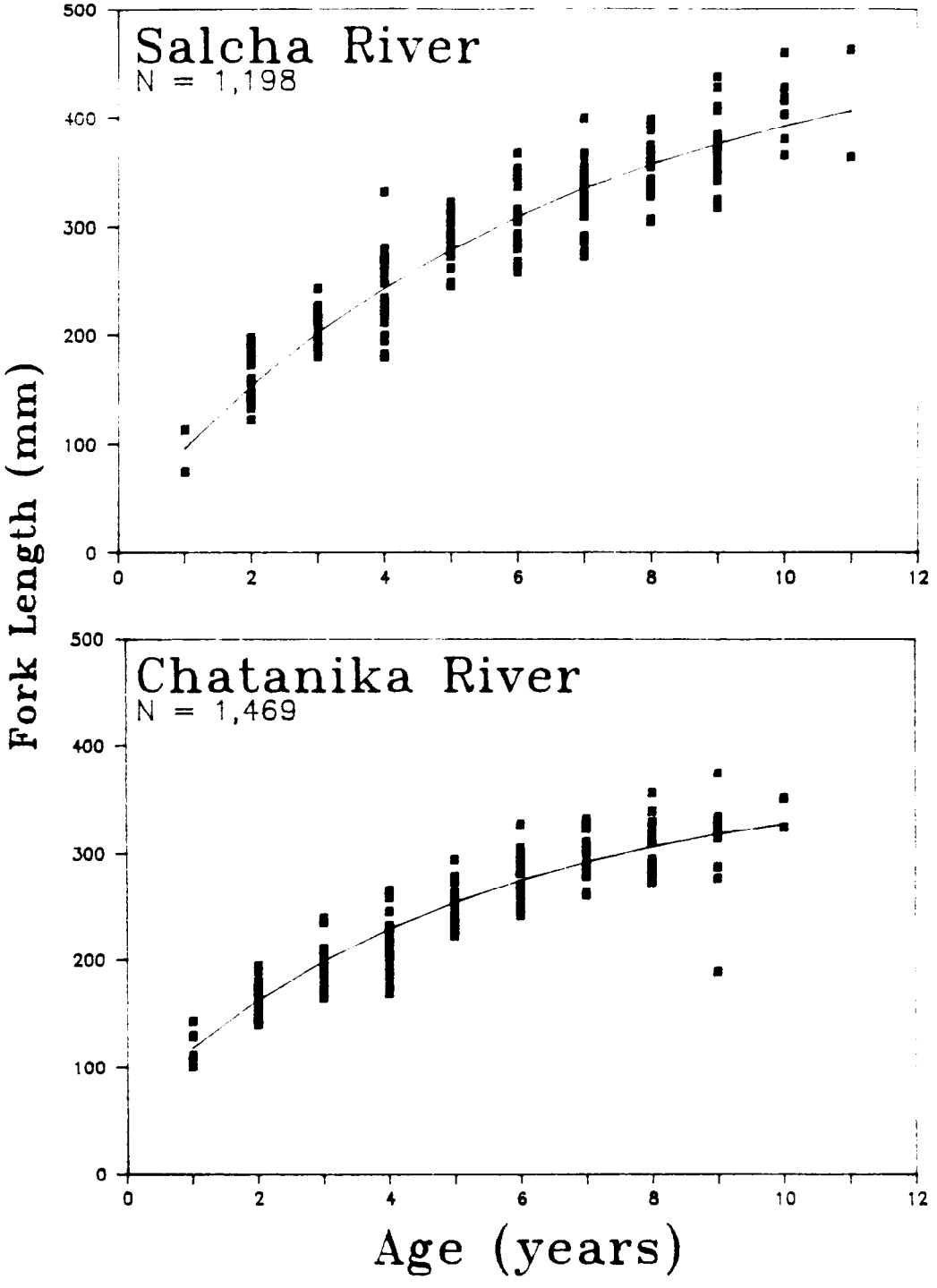

Figure 4. Growth curves of Arctic grayling from the Salcha and Chatanika Rivers. Data were collected from 1986 through 1988.

Table 7. Mean fork length at age of Arctic grayling from the Salcha and Chatanika Rivers, 1986-1988.

	Salcha River				Chatanika River			
Age Class	n[1]	FL[2]	SD[3]	SE[4]	n	FL	SD	SE
1	2	95	27	19	6	121	16	7
2	40	154	22	3	42	163	17	3
3	164	203	24	2	213	198	21	2
4	301	243	26	2	374	230	20	1
5	273	279	30	2	319	257	22	1
6	165	311	30	2	214	271	22	2
7	128	336	33	3	208	292	25	2
8	83	353	28	3	81	312	24	3
9	32	374	27	5	10	309	50	16
10	8	410	29	10	2	339	19	13
11	2	414	70	49	0	---	---	---
Totals	1,198				1,469			

[1] n is the total number of fish aged from samples taken in 1986, 1987, and 1988.
[2] FL is the arithmetic mean fork length in millimeters.
[3] SD is the population standard deviation of FL.
[4] SE is the standard error of FL.

The von Bertalanffy model of Arctic grayling growth was successfully adapted to the Chatanika River data set (Table 6; Figure 4). Standard deviations of mean fork length at age were similar among ages, excepting age 9 samples (Table 7). No samples of age 11 or older Arctic grayling were taken on the Chatanika River.

DISCUSSION

Using similar assessment approaches on the Salcha and Chatanika Rivers, the population dynamics of both stocks can be qualitatively described. Age composition is similar in the two stocks, but growth is significantly different ($T^2 = 173.90$; $df = 3, 2,663$; $P < 0.01$; see Bernard 1981). Clark and Ridder (1988) noted that the same general pattern of year class strength is evident, but that growth trends are variable among Arctic grayling stocks of the Tanana drainage. This may mean that similar fishery regulations could work among all stocks of the Tanana drainage, but that regulations incorporating length (minimum or maximum) limits must consider the growth characteristics of each stock.

Sustained yield of Arctic grayling in these two stocks cannot be calculated from the available data base of harvest and population abundance. Arctic grayling stocks tend to have one or two strong year classes that support most of the fishing pressure (Holmes 1985). Experience on the Chena River has shown that exploitation rates above 25% were not sustainable, especially when year class strength of age 4, age 5, and age 6 fish is weak (Holmes et al. 1986). Both the Salcha and Chatanika stocks have relatively strong age 5 components, but relatively weak age 3 and age 4 components (Table 4). Continued monitoring of age class structure would provide relative estimates of year class strength and a qualitative estimate of future fishery states.

Estimation of abundance on either the Salcha or Chatanika Rivers would require an expenditure of manpower similar to or greater than the Chena River abundance estimate (see Clark and Ridder 1988). The Salcha River abundance estimate was performed to provide an index of abundance for Arctic grayling in the lower Salcha River during late May to early June. The migratory nature of Arctic grayling prevented a simple Petersen estimate of abundance, but precautions were made to assess and adjust for fish movement. Because the migratory timing may be variable among years, abundance estimates performed during this time of year may not provide a reliable index of abundance. It is preferable to estimate abundance of the entire river or a section of river when fish are known not to be moving. Present manpower constraints prevent either of these alternatives. However, alternative ways of estimating exploitation and recruitment are available and must be explored. For example, with tag returns from the fishery or from test fishing, empirical estimates of survival can be calculated (Seber 1982). Using estimates of natural mortality from the Chena River (Clark in prep.), estimates of fishing mortality can be calculated. Fishing mortality along with estimates of annual harvest could be combined to give estimates of population size. Continued monitoring of tag recoveries would provide sufficient dynamic rate data to determine optimal

strategies for harvest of these two stocks. Therefore, tagging of Salcha and Chatanika River Arctic grayling should continue and possibly expand.

ACKNOWLEDGEMENTS

I wish to thank Tim Viavant and James Chumbley for their assistance in the field. Thanks also go to Jerry Hallberg, Rocky Holmes, Cal Skaugstad, Tim McKinley, and others during the Chatanika River sampling. Tim Viavant and Liz Peltola are commended for their expertise in the lab. As always, technical assistance and guidance during and after the field season was provided by John H. Clark and Dave Bernard. Thanks are also in order for Rocky Holmes and John H. Clark for reviewing early drafts of this report and providing comments. This project and report were made possible by partial funding provided by the U. S. Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-4, Job Number G-8-1.

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APPENDICES

Appendix Table 1. Summary of population abundance estimates of Arctic grayling in the Salcha River, 1972, 1974, 1985, 1988[1].

Dates	Area	Marks	Recaps	Estimate[2]	Confidence[3]
8/2-8/4/72	Redmond Creek	ND[4]	5	503/km	Low
7/10-7/22/74	Redmond Creek to TAPS[5]	ND	ND	765/km	490-5,032/km
7/10-7/22/74	TAPS to 8 km upstream	ND	ND	991/km	690-2,595/km
7/10-7/22/74	TAPS to 8 km downstream	ND	ND	551/km	397-1,174/km
8/5-8/9/85	Flat Creek	205	6	497/km	128-1,064/km
5/24-6/8/88	TAPS to 16 km upstream	208	28	138/km	SE = 34/km

[1] Data sources are:
1972 - Tack (1973);
1974 - Bendock (1974) and Kramer (1975); and,
1985 - Holmes et al. (1986).

[2] All estimates are calculated with the modified Schnabel formula (Ricker 1975) except the 1988 estimate. The 1988 estimate is calculated with a modified Petersen estimate of Evenson (1988).

[3] Confidence is a crude measure of precision (e.g. Low) or the 95% confidence interval based on a Poisson distribution of recaptures (Ricker 1975). Estimate for 1988 was from bootstrap methods (Efron 1982); a standard error (SE) is reported for this estimate.

[4] ND = data not furnished in original citation.

[5] TAPS = Trans-Alaska Pipeline System.

Appendix Table 2. Summary of age composition estimates and standard error of Arctic grayling (greater than 149 mm FL) collected from the Salcha River, 1985-1988.

	1985[1]			1986[2]			1987[3]			1988[4]		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	1	0.005	0.005	0	0.000	---	2	0.004	0.003	17	0.029	0.007
3	13	0.060	0.016	19	0.123	0.026	35	0.067	0.011	116	0.200	0.017
4	3	0.014	0.008	25	0.161	0.030	205	0.395	0.021	83	0.143	0.014
5	29	0.133	0.023	14	0.090	0.023	120	0.231	0.018	175	0.301	0.019
6	69	0.317	0.032	37	0.239	0.034	80	0.154	0.016	58	0.100	0.012
7	58	0.266	0.030	26	0.168	0.030	56	0.108	0.014	54	0.093	0.012
8	25	0.115	0.022	22	0.142	0.028	15	0.029	0.007	51	0.088	0.012
9	18	0.083	0.019	8	0.052	0.018	4	0.008	0.004	22	0.038	0.008
10	2	0.009	0.006	3	0.019	0.011	2	0.004	0.003	4	0.007	0.003
11	0	0.000	---	1	0.006	0.006	0	0.000	---	1	0.002	0.002
Totals	218	1.000		154	1.000		519	1.000		581	1.000	

[1] Sampling was conducted with an AC electrofishing boat and hook-and-line gear from river km 64.0 to river km 57.6 (5-9 August 1985).

[2] Sampling was conducted with a DC electrofishing boat and hook-and-line gear from river km 112.0 to river km 4.8 (11-15 August 1986).

[3] Sampling was conducted with a DC electrofishing boat from river km 38.4 to river km 4.8 (1-9 June 1987).

[4] Sampling was conducted with a DC electrofishing boat from river km 38.4 to river km 16.0 (24 May through 9 June 1988).

Appendix Table 3. Summary of mean length at age data collected from Arctic grayling in the Salcha River, 1952, 1974, 1981, 1985-1988[1].

	1952			1974			1981			1985			1986			1987			1988		
Age Class	n[2]	FL[3]	SD[4]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	ND[5]	103	---	6	111	---	20	126	---	---	---	---	---	---	---	---	---	---	---	---	---
2	ND	145	---	88	155	---	25	162	---	1	156	---	---	---	---	2	138	8	17	174	16
3	ND	185	---	61	196	---	11	197	---	13	223	15	19	218	16	35	203	36	116	200	16
4	ND	223	---	26	231	---	9	224	---	3	262	18	25	263	25	205	241	20	83	241	20
5	ND	261	---	16	278	---	7	254	---	29	292	10	14	291	26	120	275	33	175	280	24
6	ND	289	---	3	345	---	5	272	---	69	313	20	37	316	24	80	311	36	58	302	30
7	ND	318	---	---	---	---	8	302	---	58	332	16	26	328	40	56	339	30	54	332	32
8	---	---	---	---	---	---	5	335	---	25	346	15	22	360	30	15	356	36	51	348	24
9	---	---	---	---	---	---	1	353	---	18	378	24	8	372	18	4	371	30	22	373	30
10	---	---	---	---	---	---	---	---	---	2	403	90	3	405	16	2	444	20	4	394	19
11	---	---	---	---	---	---	---	---	---	---	---	---	1	364	---	---	---	---	1	463	___
Totals	32			200			91			219			155			519			581		

[1] Data sources: 1952 - Warner (1959); 1974 - Bendock (1974) and Kramer (1975); 1981 - Hallberg (1982); 1985 - Holmes et al. (1986); 1986 - Clark and Ridder (1987); and, 1987 - Clark and Ridder (1988).

[2] n is the total number of fish aged.

[3] FL is the population mean fork length at age.

[4] SD is the population standard deviation of FL.

[5] ND = data not furnished in original citation.

Appendix Table 4. Summary of Relative Stock Density (RSD) indices of Arctic grayling captured in the Salcha River, 1972, 1974, 1985-1988[1].

	RSD Category[2]				
	Stock	Quality	Preferred	Memorable	Trophy
1972 - Number sampled	ND[3]	ND	ND	ND	ND
RSD	0.534	0.462	0.004	0.000	0.000
SE	ND	ND	ND	---	---
1974 - Number sampled	153	14	2	0	0
RSD	0.905	0.083	0.012	---	---
SE	0.022	0.021	0.008	---	---
1985 - Number sampled	17	155	57	0	0
RSD	0.074	0.677	0.249	---	---
SE	0.017	0.031	0.029	---	---
1986 - Number sampled	47	71	56	0	0
RSD	0.270	0.408	0.322	---	---
SE	0.034	0.037	0.036	---	---
1987 - Number sampled	275	171	71	1	0
RSD	0.531	0.330	0.137	0.002	---
SE	0.022	0.021	0.015	0.002	---
1988 - Number sampled	280	217	110	1	0
RSD	0.461	0.357	0.181	0.002	---
SE	0.020	0.019	0.016	0.002	---

[1] Data sources:
- 1972 - Tack (1973);
- 1974 - Bendock (1974) and Kramer (1975);
- 1985 - Holmes et al. (1986);
- 1986 - Clark and Ridder (1987); and,
- 1987 - Clark and Ridder (1988).

[2] Minimum lengths for RSD categories are (Gablehouse 1984):
- Stock - 150 mm FL;
- Quality - 270 mm FL;
- Preferred - 340 mm FL;
- Memorable - 450 mm FL; and,
- Trophy - 560 mm FL.

[3] ND = data not furnished in original citation.

Appendix Table 5. Summary of population abundance estimates of Arctic grayling in the Chatanika River, 1972, 1981, 1984-1985[1].

Dates	Area	Marks	Recaps	Estimate[2]	Confidence[3]
8/10-8/17/72	Elliot Highway Bridge	103	4	305/km	Low
8/24-8/26/81	Elliot Highway Bridge	ND[4]	64	169/km	132-197/km
8/15-8/18/84	Elliot Highway Bridge	ND	32	242/km	172-352/km
8/20-8/23/85	Elliot Highway Bridge	132	20	117/km	82-176/km

[1] Data sources are:
1972 - Tack (1973);
1982 - Holmes (1983);
1984 - Holmes (1985); and,
1985 - Holmes et al. (1986).

[2] All estimates are calculated with the modified Schnabel formula (Ricker 1975).

[3] Confidence is a crude measure of precision (e.g. Low) or the 95% confidence interval based on a Poisson distribution of recaptures (Ricker 1975).

[4] ND = data not furnished in original citation.

Appendix Table 6. Summary of age composition estimates and standard error of Arctic grayling (greater than 149 mm FL) collected from the Chatanika River, 1984-1988.

	1984[1]			1985[2]			1986[3]			1987[4]			1988[5]		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	2	0.036	0.025	131	0.550	0.032	0	0.000	---	11	0.020	0.006	22	0.043	0.009
3	8	0.143	0.047	5	0.021	0.009	119	0.308	0.023	50	0.090	0.012	44	0.085	0.012
4	22	0.393	0.066	31	0.130	0.022	16	0.041	0.010	295	0.553	0.021	63	0.122	0.014
5	17	0.304	0.062	59	0.248	0.028	71	0.184	0.020	32	0.058	0.010	216	0.419	0.022
6	5	0.089	0.038	12	0.050	0.014	119	0.308	0.023	47	0.085	0.011	48	0.093	0.013
7	1	0.018	0.018	0	0.000	---	47	0.122	0.017	106	0.192	0.017	55	0.107	0.014
8	1	0.018	0.018	0	0.000	---	12	0.031	0.009	8	0.014	0.005	61	0.118	0.014
9	0	0.000	---	0	0.000	---	2	0.005	0.004	3	0.005	0.003	5	0.010	0.004
10	0	0.000	---	0	0.000	---	0	0.000	---	1	0.002	0.002	1	0.002	0.002
Totals	56	1.000		238	1.000		386	1.000		553	1.000		515	1.000	

1 Sampling was conducted with an AC electrofishing boat near the Elliot Highway bridge (15-18 August 1984).
2 Sampling was conducted with an AC electrofishing boat near the Elliot Highway bridge (20-23 August 1985).
3 Sampling was conducted with a DC electrofishing boat near the Elliot Highway bridge (4-28 August 1986).
4 Sampling was conducted with a DC electrofishing boat near the Elliot Highway bridge (10-13 August 1987).
5 Sampling was conducted with a DC electrofishing boat near the Elliot Highway bridge (15-26 August and 7-20 September 1988).

Appendix Table 7. Summary of mean length at age data collected from Arctic grayling in the Chatanika River, 1952-1953, 1981-1982, 1984-1988[1].

	1952			1953			1981			1982			1984			1985		
Age Class	n[2]	FL[3]	SD[4]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	ND[5]	94	---	19	96	---	0	---	---	5	95	---	16	101	---	0	---	---
2	ND	133	---	77	144	---	4	169	---	29	135	---	3	149	---	131	147	15
3	ND	176	---	129	190	---	7	204	---	22	187	---	8	172	---	5	181	25
4	ND	212	---	28	207	---	10	233	---	23	216	---	22	196	---	31	212	22
5	ND	243	---	4	226	---	7	264	---	5	236	---	17	225	---	59	233	24
6	---	---	---	9	254	---	3	286	---	2	280	---	5	251	---	12	268	18
7	---	---	---	---	---	---	1	290	---	1	252	---	1	258	---	---	---	---
8	---	---	---	---	---	---	---	---	---	1	334	---	1	301	---	---	---	---
9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Totals	149			266			32			88			73			238		

- Continued -

Appendix Table 7. Summary of mean length at age data collected from Arctic grayling in the Chatanika River, 1952-1953, 1981-1982, 1984-1988[1] (Continued).

	1986			1987			1988		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD
1	---	---	---	---	---	---	---	---	---
2	---	---	---	11	157	15	22	170	13
3	119	195	21	50	200	24	44	205	16
4	16	231	36	295	228	18	63	238	21
5	71	248	16	32	265	22	216	259	22
6	119	267	20	47	273	21	48	278	24
7	47	292	28	106	288	30	55	298	22
8	12	304	21	8	319	18	61	312	25
9	2	283	35	3	296	55	5	328	8
10	---	---	---	1	325	___	1	352	---
Totals	386			553			515		

[1] Data sources: 1952-1953 - Warner (1959); 1981 - Hallberg (1982); 1982 - Holmes (1983); 1984 - Holmes (1985); 1985 - Holmes et al. (1986); 1986 - Clark and Ridder (1987); 1987 - Clark and Ridder (1988).

[2] n is the total number of fish aged.

[3] FL is the population mean fork length at age.

[4] SD is the population standard deviation of FL.

[5] ND = data not furnished in original citation.

Appendix Table 8. Summary of Relative Stock Density (RSD) indices of Arctic grayling captured in the Chatanika River, 1952-1954, 1972, 1982, 1984-1988[1].

		RSD Category[2]				
		Stock	Quality	Preferred	Memorable	Trophy
1952	Number sampled	95	1	0	0	0
	RSD	0.990	0.010	---	---	---
	SE	0.010	0.010	---	---	---
1953	Number sampled	98	8	0	0	0
	RSD	0.925	0.075	---	---	---
	SE	0.026	0.026	---	---	---
1954	Number sampled	42	1	0	0	0
	RSD	0.977	0.023	---	---	---
	SE	0.023	0.023	---	---	---
1972	Number sampled	121	0	0	0	0
	RSD	1.000	---	---	---	---
	SE	---	---	---	---	---
1982	Number sampled	53	3	0	0	0
	RSD	0.946	0.054	---	---	---
	SE	0.030	0.030	---	---	---
1984	Number sampled	206	9	1	0	0
	RSD	0.954	0.042	0.005	---	---
	SE	0.014	0.014	0.005	---	---
1985	Number sampled	146	11	0	0	0
	RSD	0.930	0.070	---	---	---
	SE	0.020	0.020	---	---	---
1986	Number sampled	279	121	4	0	0
	RSD	0.691	0.300	0.010	---	---
	SE	0.023	0.023	0.005	---	---
1987	Number sampled	420	126	7	0	0
	RSD	0.759	0.228	0.013	---	---
	SE	0.018	0.018	0.005	---	---
1988	Number sampled	361	221	13	0	0
	RSD	0.607	0.371	0.022	---	---
	SE	0.020	0.020	0.006	---	---

- Continued -

Appendix Table 8. Summary of Relative Stock Density (RSD) indices of Arctic grayling captured in the Chatanika River, 1952-1954, 1972, 1982, 1984-1988[1] (Continued).

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[1] Data sources:
1952-1958 - Warner (1959);
1972 - Tack (1973);
1982 - Holmes (1983);
1984 - Holmes (1985);
1985 - Holmes et al. (1986);
1986 - Clark and Ridder (1987); and,
1987 - Clark and Ridder (1988).

[2] Minimum lengths for RSD categories are (Gablehouse 1984):
Stock - 150 mm FL;
Quality - 270 mm FL;
Preferred - 340 mm FL;
Memorable - 450 mm FL; and,
Trophy - 560 mm FL.